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(30) Priority: 15.01.2002 JP 2002006240 11.06.2002 JP 2002170496 Applicant: Sumitomo Electric Industries, Ltd. Osaka-shi, Osaka 541-0041 (JP) Ξ

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Yokohama-shi, Kanagawa 244-8588 (JP) fokohema-shi, Kanagawa 244-8588 (JP) Hatton, Tomoyuki, Yokohama Works Sassoka, Elsuke, Yokohama Works 2

(74) Representative: HOFFMANN - EITLE Patent- und Rechtsanwälte 81925 München (DE) Arabellastrasse 4.

Optical fiber, optical fiber tape, optical cable, and optical connector with optical fiber

sible to transmit signals with a high bit rate in both of this optical fiber is configured so as to have a mode field The present invention relates to an optical fiber and the like comprising a structure enabling high-density packaging into an optical cable while making it poswavelength bands of 1.3 µm and 1.55 µm. For example (57)

diameter of 8.0 µm or less at a wavelength of 1.55 µm, a cutoff wavelength of 1.26 µm or less, and a chromatic dispersion with an absolute value of 12 ps/nm/km or less al wavelengths of 1.3 µm and 1.55 µm, thereby yielding an excellent lateral pressure resistance enabling highdensity packaging into an optical cable

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Description

BACKGROUND OF THE INVENTION

Field of the Invent

able for an optical transmission line through which signal st, an.optical fiber tape, an optical cable, and an optical connector equipped with an optical fiber, which are suitlight propagates, an optical transmission line of optical The present invention relates to an optical fib. access type in particular, in an optical communication

Related Background Art

lines. As an optical transmission line through which the Optical communication systems enable highspeed transmission of a large volume of information by transmitting signal light through optical transmission signal light propagates, an optical fiber is employed, for which is a material for an optical fiber, becomes zero in tical fibers for the band of 1.3 µm having a zero-dispersion wavelength near the wavelength of 1.3 µm have cations in the band of 1.55 µm, having a zero-dispension mi, et al., "Optical fiber and Fiber type Devices", Balfuexample. Since the chromatic dispersion of silica glass, the vicinity of a wavelength of 1.3 µm, single-mode opbeen utilized in conventional optical communication systems. Also proposed is a single-mode optical fiber wavelength near the wavelength of 1.3 µm. Further, taking account of the fact that the transmission loss of silica glass is minimized at a wavelength of 1.55 µm, a dispersion-shifted optical fiber whose refractive index profile is designed so as to attain a zero-dispersion wavelength near the wavelength of 1.55 µm has been utilized Structures and characteristics of such optical fibers are for the band of 1.65 µm, sultable for optical communithe above-mentioned optical transmission line. described, for example, In literature 1 -- Shojiro Kawakakan, July 10, 1996, pp. 80-113.

wavelength between wavelengths of 1.3 µm and 1.55 um have been proposed as disclosed in Japanese Patant Application Laid-Open No. HEi 11-281840 and literature 2 -- K. Nakajima, et al., "Design consideration for Also, optical fibers having a zero-dispension 38 µm zero-dispersion (iber for access and metropoltan networks", The 2001 IEICE Communications Socialy Conference, SB-12-1 (2001).

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SUMMARY OF THE INVENTION

[0004] The inventors studied the conventional optical communication systems and, as a result, have found the following problems. The above-mentioned literature 1 suggests that the single-mode optical fibers for the .3-µm band are interior to the single-mode optical fibars and dispersion-shifted optical fibers for the 1.55-µm

band in terms of the bending loss characteristic in the packaged with a high denatry into an optical cable and .55-µm band. Such 1.3-µm band single-mode optical libers may incur targe macrobend and microbend losses In the 1.55-um band, thus yielding a large loss when when wound like a coll upon excess-langth processing and the like. Therefore, the single-mode optical fibers for the 1.3-µm band are hard to package with a high donsity into an optical cable, and its compact excess-length processing is difficult.

Also, the single-mode optical fibers for the 1.3-µm band havo a chromatic dispersion with a largo absolute value in the 1.55 μm wavelength band, which makes it difficult to transmit signals with a high bit rate in the 1.55-um band. The same holds for the alngiomode optical fibers for the 1.55-um band. On the other hand, the dispersion-shifted optical fibers have a chromatic dispersion with large absolute value in the 1.3-µm wavelength band, which makes it difficult to transmit signets with a high bit rate in the 1.3 um band. 5

(0006) By contrast, the optical fibers disclosed in the Open No. HEI 11-281840 and literature 2 have a zerodispersion wavelength between wavelengths of 1.3 µm and 1.55 μm, thus exhibiting a chromatic dispersion with length bands of 1.3 µm and 1.65 µm, which makes it possible to transmit signals with a high bit rate in both above-mentioned Japanese Patent Application Laida relatively small absolute value in both of the waveof these wavelength bands.

[0007] However, the optical fibors disclosed in the above-mentioned Japanase Patent Application Laid. Open No. HEI 11-281840 and literature 2 have been designed for use in middle to long-haul transmissions based on a wavelength division multiplaxing (WDM) <u> Vansmission system for transmitting multiplexed signal</u> light (WDM eignel light) having a pturality of channels. Namely, it is preferred that these optical fibers have an effective area as large as possible so as to restrain sigcal phenomena even when signal light having a large to long-haul transmissions, but not intended for highdensity packaging within an optical cable. Hence, there is a possibility of microband loss occurring when the opticel fibers are packaged with a high density within an nal waveforms from deterlorating due to nonlinoar opti power propagates therathrough. Also, these optical fib ers are assumed to be used in optical cables for middle. optical capte

In order to overcome the problems mentioned above, it is an object of the present invention to provide an optical fiber comprising a structure enabling highpossible to transmit signals with a high bit rate in both fiber tape including the optical fiber, an optical cable including the optical fiber, and an optical connector density packaging into an optical cable while making it of wavelength bands of 1.3 µm and 1.55 µm, an optical

The optical liber according to the present invention comprises various structures making it possible [6000]

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length bands of 1.3 µm and 1.55 µm, having such an packaging in optical cables, and enabling high-density to transmit signals with a high bit rate in both of waveexcellent lateral pressure resistance that loss is effecrestrained from increasing even upon severe packaging into optical cables.

tioned as it is refers to cable cutoff wavelength, whereas present invention comprises a core region extending along a predetermined axis and a cladding region provided on the outer periphery of the core region, and has a cutoff wavelength of 1.26 µm or less but preferably 1.0 in this specification, "cutoff wavelength" when men-Specifically, the optical fiber according to the μπ or more, and a mode field diameter of 8.0 μm or tess, preferably 6.5 µm or less, at a wave length of 1.55 µm. "mode field diameter" when mentioned as it is refers to Petermann-I mode field diameter. [0010]

[0011] It will be tolerable if the mode field diameter at a wavelength of 1.55 µm is 7.0 µm or more but 8.0 µm or less even when exceeding 6.5 µm. It will be sufficient if the mode field diameter at a wavelength of 1.55 µm is a mode field diameter of 5 µm or more at a wavelength of 1.3 µm can effectively restrain splice loss from increasing upon connecting with another optical fiber, and 5.0 µm or more, preferably 6.0 µm or more. In particular, can effectively restrain splice loss from increasing due to axial misalignment when such optical fibers are con-

8 Ŋ mit signals with a high bit rate in both of the wavelength bands of 1.3 µm and 1.55 µm, the optical fiber having [0012] Preferably, in order to make it possible to transwavelengths of 1.3 µm and 1.55 µm. For enabling high-density packaging into an optical cable by improvof 1.55 µm. For improving the high-density packaging state within the optical cable and the long-term reliability long-haul transmissions, the optical fiber comprising the above-mentioned structure may have a transmission the structure mentioned above further has a chromatic dispersion with an absolute value of 12 ps/nm/km or less comprising the above-mentioned structure may have a proof level of 1.2% or more in a proof test. For enabling ing a lateral pressure resistance, the optical fiber comprising the structure mentioned above may further have a microbend loss of 0.1 dB/km or less at a wavelength in a state bent into a small diameter, the optical fiber loss of 0.5 dB/km or less at a wavelength of 1.3 µm.

[0013] While the transmission loss at a wavelength of 1.3 µm is 0.5 dB/km or less, the transmission loss at a the optical cable or the long-term reliability in a state bent into a small diameter, the optical fiber according to For improving the high-density packaging state within wavelength of 1.55 µm is preferably 0.3 dB/km or less. the present invention has a fatigue coefficient n of 50 or more. In the proof test, each optical fiber preferably has a proof level of 1.2% or more, more preferably 2% or more, 3% or more, or 4% or more. When the optical fiber according to the present invention attains a proof tevel of 1.2% or more in the proof test, it can secure a long-

fiber at that time refers to the ratio of elongation of the cal liber to be measured and the like, and is given as a state within the optical cable or bent into a small diameter. Here, the proof test is a test for applying a tension sion applied to the optical fiber in the proof test is determined according to the cross-sectional area of the optito an optical fiber, whereas the proof level of the optica optical fiber when the tension is applied thereto. The tenvalue inherent in each optical fiber.

at a diameter of 20 mmat a wavelength of 1.55 μm. In even when bent into a small diameter upon excesslength processing by winding like a coil at a terminal of according to the present invention has a bending loss [0014] Preferably, the optical fiber according to the present invention has a bending loss of 0.1 dB/m or lass this case, the increase in loss of the optical fiber is small an optical cable and the like. Preferably, the optical liber of 0.1 dB/m or less at a diameter of 15 mm at a wavelength of 1.55 µm, and a bending loss of 0.1 dB/m or [0015] The optical fiber according to the present inprovided on the outer periphery of the core region as less at a diameter of 10 mm at a wavelength of 1.55 μm. vention comprises a core region and a cladding region mentioned above. When the cladding region is consti-tuted by a single silica glass material, the optical fiber has such a refractive index profile that a part corresponding to the core region has a substantially singlepeak form whereas the part corresponding to the cladding region has a substantially list form. The cladding The optical fiber is easy to make in each case since its meting an α -power distribution where $\alpha \approx 1$ to 5 within prising an inner cladding having a lower refractive index profile form is relatively simple. Preferably, the optical fiber has a refractive index profile with a form approxi-Index to a part yielding half the maximum refractive inregion may have a depressed cladding structure comand an outer cladding having a higher refractive index. the range from a part yielding the maximum refractive dex in a portion corresponding to the core region. 5 8

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[0016] The refractive index profile mentioned above is obtained when the core region is constituted by silica glass doped with GeO_2 whereas the cladding region is constituted by pure silica glass or silica glass doped with F in the case where the cladding region has a depressed cladding structure, this structure is formed when the inner cladding is constituted by silica glass doped with F whereas the outer cladding is constituted profile is obtained when each glass region is doped with by pure silica glass. Thus, a destrable refractive index a refractive index adjusting dopant. ç

60 to 100 µm as well. When the outer diameter is 60 to vention, the cladding region has an outer dlameter of 125±1 µm in general, though the outer dlameter may be 100 µm, the possibility of the optical fiber breaking due eter decreases, thereby improving its long-term reliabil-[0017] In the optical fiber according to the present into bending distortions upon bending into a small diam-

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imum outer diameters in the cladding region is 1.0 µm lty. Here, the difference between the maximum and minor less, preferably 0.5 µm or less. The amount of core the center of the cladding region and the center of the core region is preferably 0.5 µm or less, more preferably eccentricity defined by the amount of deviation between

en optical cable, thereby making it possible to reduce the diameter of the optical cable or increase the number periphery of the dadding region. Preferably, the coating ficiency when the optical fiber is accommodated within [0018] The optical fiber according to the present invention may further comprise a coating layer at the outer layer has an outer diameter of 250±30 μm or 200 μm or less. In particular, a coating tayer having an outer diameter of 200 µm or less improves the accommodating ef-0.2 µm or less, in order to reduce the splice toss.

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[0019] The coating layer may be constituted by a single layer or a double structure comprising inner and outof optical fibers accommodated therein.

er coatings, whereas its thickness is preferably 15 µm. hand, it is preferred that the inner coating have a or more but 37.5 µm or less. When the coating layer is a single layer, its Young's modulus is preferably 10 kg/ ture constituted by inner and outer coatings, on the other Young's modulus of 0.2 kg/mm² or less and that the outer coating have a Young's modulus of 10 kg/mm² or ${f m}^2$ or more. When the coating layer has a double strucmore. Here, the outer coating has a thickness of 15 µm

8 For further decreasing the possibility of breaking due to bending distortions upon bending into a small diameter (i.e., improving the long-term reliability), the bly has a fatigue coefficient n of 50 or more. In this case, the optical liber may further comprise a carbon coat disoptical fiber according to the present invention prefereposed between the cladding region and the coating lay-[0050]

or more.

\$ [0021] The optical fiber comprising the structure menponents. For example, the optical fiber tape according iber having the structure mentioned above (the optical iber according to the present invention). Also, the oplioned above can be employed in various optical comto the present invention comprises a plurality of optical fibers integrally coated with a resin, whereas each of the optical fibers has a structure similar to that of the optical lical cable according to the present invention includes a plurality of optical fibers each having a structure similar to that of the optical fiber having the structure mentioned above (theoptical fiber, according to the present nvention). Further, the optical connector equipped with unses an optical fiber having the structure mentioned an optical fiber according to the present invention comion) and a connector attached to a leading end part of sbove (the optical tiber according to the present inven

BRIEF DESCRIPTION OF THE DRAWINGS

ing to the present invention, whereas Fig. 1B is a 1A is a view showing a cross-sectional structure in a first embodiment of the optical liber eccordrefractive index profile thereof;

Figs. 2A to 2C are various refractive index profiles Fig. 3A is a view showing a cross-sectional strucof the optical fiber according to the first embodi-

ture in a second embodiment of the optical fibor ac-cording to the present invention, whereas Fig. 3B is a refractive index profile thereof;

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Figs. 4A and 4B are views showing cross-sectional structures of coating layers in optical fibers accord ing to the present invention;

characteristic of an optical (iber according to the Fig. 5 is a graph showing the chromatic dispersion present invention;

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Fig. 6 is a graph showing a favorable range example of the relative refractive index difference A and outer diameter 2a in the core region in the optical liber according to the first embodiment;

Fig. 7 is a table listing various items in each of the optical fibers of sample Nos. 1 to 5;

Fig. 8 is a view showing a schamatic structure of an optical fiber tape according to the present invention; Fig. 9 is a view showing a schematic structure of en optical connector equipped with an optical fiber ac-

Fig. 10A is a view showing a achematic structure of an optical cable according to the present invention, whereas Fig. 10B is a view showing a cross-sec. cording to the present invention; and tional structure thereof.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

explained in detail with reference to Figs. 1A to 4B, 5 to In the following, embodiments of the optical (iber and the like according to the present invention will be 9, 10A, and 10B. In the explanation of the drawings, constituents identical to each other will be referred to with numerals identical to each other without repeating their overlapping descriptions. \$

structure of a first embodiment of the optical fiber acwhereas Fig. 18 is a refractive index profile 20 indicating [0024] Fig. 1A is a view showing a cross-sectional cording to the present invention, whereas Fig. 1B is a refractive Index profile thereof. In particular, Fig. 1A shows a cross section of the optical fiber 10 according L1 in Fig. 1A. The optical fiber 10 according to the first to the first embodiment orthogonal to the optical axis, the refractive index of each glass region along the line embodiment comprises a core region 11 having an outer diameter 2a and extending along the optical axis, a ctad-8

ing an outer diameter 2d and surrounding the cladding ding region 12 having an outer diameter 2b and surregion 12. For further lowering the possibility of breaking due to bending distortions upon bending into a small diameter (to improve the long-term reliability), a carbon coat 60 may be disposed between the cladding region rounding the core region 11, and a coating layer 50 hav 12 and the coating layer 50.

cifically, the refractive index profile 200 is obtained when the core region 11 is constituted by silica glass doped with ${\rm GeO}_2$ whereas the cladding region 12 is constituted core region 11 in the refractive index profile 200 has a dex profile 200 preferably has a form approximating an from a part yielding the maximum refractive index to a The core region 11 and cladding region 12 are mainly composed of silica glass (SiO $_2$), whereas at least one of the core region 11 and cladding region 12 is doped with impurities for adjusting refractive index. Speby pure stitca glass or silica glass doped with F. The refrective Index n, of the core region 11 is higher than the in the first embodiment, the part corresponding to the substantially single-peak form. Here, the refractive in- α -power distribution where $\alpha=1$ to 5 within the range part yielding half the maximum refractive index in the er hand, it is preferred that the part corresponding to the cladding region 12 in the refractive index profile 200 liber 10 is easy to make, since its profile form is relatively refractive index n₂ of the cladding region 12. Preferably have a substantially flat form. In this case, the optical portion corresponding to the core region 11. On the oth-

the refractive indices of the core region 11 and cladding 18 indicates the refractive index of each part along the fractive index difference Δ_1 of the core region 11 (having the refractive index n₁) with reference to the cladding region 12 (having the refractive index n_2) is given by (n, The refractive Index profile 200 shown in Fig. line L1 in Fig. 1A, whereby areas 201 and 202 indicate region 12 on the line L1, respectively. The relative re-[0026]

ş index profiles 210 to 230 shown in Figs. 2A to 2C. The form that the area 212 corresponding to the cladding resingle-peak form" includes not only ideal stepped forms refractive index profile 210 shown in Fig. 2A has such a corresponding to the core region 11 have a refractive The refractive index profile in which the part corresponding to the core region 11 has *a substantially such as the one shown in Fig. 18, but also refractive gion 12 has a constant refractive index while the center has a refractive index higher than that of its peripheral parts. The refractive index profile 220 shown in Fig. 28 has a substantially stepped form such that the area 222 part of the area 211 corresponding to the core region 11 corresponding to the cladding region 12 has a constant ndex slightly higher than that of the center part. The reractive index profile 230 shown in Fig. 2C has a subrefractive index while peripheral parts of the area 221 stantially stepped form such that the area 232

sponding to the cladding region 12 has a constant refractive index while the refractive Index gradually decreases in peripheral parts of the area 231 correspond ng to the core region 11.

the line L2 in Fig. 3A. The optical fiber 20 according to according to the present invention, whereas Fig. 3B is caling the refractive index of each glass region along [0028] Fig. 3A is a view showing a cross-sectiona structure of a second embodiment of the optical fiber a refractive index profile thereof. In particular, Fig. 3A shows a cross section of the optical fiber 20 according to the second embodiment orthogonal to the optical axls, whereas Fig. 3B is a refractive index profile 240 Indithe second embodiment comprises a core region 21 having an outer diameter 2a and extending along the optical axis, a ctadding region 24 surrounding the core region 21, and a coating layer 50 having an outer diameter 2d and surrounding the cladding region 24. In parbodiment is characterized in that the cladding region 24 has a depressed cladding structure. Namely, the cladding region 24 comprises an inner cladding 22 having an outer diameter 2b and surrounding the core region 21, and an outer cladding 23 having an outer dlameter lowering the possibility of breaking due to bending distortions upon bending into a small diameter (to improve ticular, the optical fiber 200 according to the second em-2c and surrounding the inner cladding 22. For further the long-term reliability), a carbon coat 60 may be disposed between the outer cladding 23 and the coating 8

one of the core region 21 and cladding region 24 is [0029] The core region 21 and cladding region 24 are mainly composed of silica glass (SiO₂), whereas at least by silica glass doped with F while the outer cladding 23 cifically, In the refractive index profile 240, the core re-The depressed cladding structure of the cladding region 24 is obtained when the inner cladding 22 is constituted is constituted by pure silica glass. The refractive index n, of the core region 21 is higher than each of the rein the second embodiment, the part corresponding to doped with impurities for adjusting refractive index. Spegion 21 is constituted by silica glass doped with GeO₂, fractive index n₂ of the inner cladding 22 and the refraclive index n₃ (> n₂) of the outer cledding 23. Preferably, the core region 21 in the refractive index profile 240 has a substantially single-peak form. Here, the refractive index profile 240 preferably has a form approximating an α -power distribution where $\alpha = 1$ to 5-within the range from a part yielding the maximum refractive index to a portion corresponding to the core region 21. In this case, the optical fiber 20 is easy to make, since its profile form part yielding half the maximum refractive index in the The refractive index profile 240 shown in Fig. is relatively simple. \$

3B indicates the refractive index of each part along the line L2 in Fig. 3A, whereby areas 241, 242, and 243 indicate the refractive indices of the core region 21, inner cladding 22, and outer cladding 23 on the line L2,

spectively. The relative refractive index difference Δ_1 of the core region 21 (having the refractive index n₁) with reference to the outer cladding 23 (having the refractive refractive index difference Δ_2 of the inner cladding 22 er cladding 23 (having the refractive index n₃) is given index n₃) is given by (n₁ - n₃)/n₃, whereas the relative (having the refractive index n₂) with reference to the out-

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[0031] In the refractive index profile 240 of the optical fiber 20 according to the second embodiment, the part ideal stepped forms such as the one shown in Fig. 3B, but also forms similar to those of the part corresponding to the core region in the refractive index profiles 210 to corresponding to the core region 21 may have not only 230 shown in Figs. 2A to 2C.

8 [0032] Though each of the respective cladding regions 12, 24 in the optical fibers 10, 20 according to the first and second embodiments has an outer diameter of $125\pm1~\mu m$ in general, the outer diameter may be 60 to 100 μm as well. When the outer diameter is 60 to 100 upon bending into a small diameter decreases in each of the optical fibers 10, 20, thereby improving its longmum and minimum outer diameters in the dadding rela preferably 0.5 µm or less, more preferably 0.2 µm or less, in order to reduce the splice loss (see Fig. 4A). μm, the possibility of breaking due to bending distortions lerm reliability. Here, the difference between the maxiof deviation between the center O₁ of the cladding region 12, 24 and the center O_2 of the core region 11, 21 glon 12, 24 is 1.0 µm or less, preferably 0.5 µm or less. The core eccentricity amount Ac defined by the amount [0033] The optical fiber 10, 20 having the above-men-

2 prise a coating layer 50 having an outer diameter of 12, 24. On the other hand, the coating layer 50 with an accommodated within an optical cable, thereby making t possible to reduce the diameter of the optical cable or lioned refractive index profile 200 to 240 (the optical fiber eccording to the present invention) may further com-250±30 µm at the outer periphery of the cladding region outer diameter 2d of 200 µm or less improves the accommodating efficiency when the optical fiber 10, 20 is ncrease the number of optical fibers accommodated

[0034] The coating layer 50 may be constituted by a single layer as shown in Fig. 4A or a double structure modulus is preferably 10 kg/mm² or more. When the the inner coating 50s and outer coating 50b (see Fig. 4B), it is preferred that the Young's modulus be 0.2 kg/mm² or less in the inner coating 50s and 10 kg/mm² or comprising en inner coating 50e and an outer coating ng layer 50 ks a single tayer (see Fig. 4A), its Young's coating layer 50 has a double structure constituted by more in the auter coating 50b. Here, the thickness of the 50b as shown in Fig. 4B, whereas its width w is prefer ably 15 µm or more but 37.5 µm or less. When the cost outer coating 50b is 15 µm or more.

0035] Each of the optical fibers 10, 20 according to the first and second embodiments having various refrac-

Invention) has a cable cutoff wave length of 1.28 µm or mode field diameter at the wavelength of 1.55 µm may of 1.3 µm may be 5.0 µm or more, more preferably 6.0 ameter of 5 µm or more at a wavelength of 1.3 µm can etrain splice loss from increasing due to axial misalign-ment when auch optical fibers are connected together. [0038] Here, the mode field diameter MFD according less but proferably 1.0 µm or more, and a Potermann-I mode field dlameter of 8.0 µm or less, preferably 8.5 µm or less, at a wavelength of 1.55 µm. The Patermann-I The Petermann-I mode field diameter at the wavelength um ormore, in particular, a Petermann-I mode field dieffectively restrain splice loss from increasing upon contive index profiles (optical fibers according to the present exceed 6.5 µm If it is 7.0 µm or more but 8.0 µm or less. necting with another optical fiber, and can effectively reto the Petermann-i definition is given by the following expression: 5

$$MFD = 2 \left(2 \left(\int_{\mathbb{R}} \phi^2(r)^{-2} dr \right)^{\frac{1}{2}} \right)$$

the wavelength of light. The cable cutoff wavelength is the cutoff wavelength of LP 11 mode at a length of 22 mm, and is a value smellor than the 2-m cutoff waveagating through the optical fiber 10, 20 and depends on where the variable r is the radial distance from the optical axis of the optical fiber 10, 20, and $\phi(t)$ is the clocind field distribution along a radial direction of the light propfengih.

having the structure mentioned above further has a bands of 1.3 µm and 1.55 µm, the optical fiber 10, 20 chromatic dispersion with an absolute value of 12 ps/ as shown in Fig. 5. For anabiing high-density packaging [0037] Preferably, in order to make it possible to transmit signals with a high bit rate in both of the wavelength nm/km or less at wavelengths of 1.3 µm and 1.55 µm into an optical cable by improving a lateral pressure re-0.1 dB/km or less at a wavolength of 1.55 µm. For lm-proving the high-density packaging state within the aptical cable or the long-term reliability in a state bent into mentioned above may further have a microbend loss of a small dlameter, the optical liber 10, 20 comprising the above-mentioned structure may have a proof level of 1.2% or more in a proof test. For enabiling tong-haul sistance, the optical fiber 10, 20 comprising the structure transmissions, the optical fiber 10, 20 comprising the above-mentioned structure may have a transmission loss of 0.5 dB/km or less at a wavelength of 1,3 µm. Here, Fig. 5 is a graph showing the chromatic dispersion characteristic of an optical fiber according to the present Invention. ş Ş 8 5

(0038) While the transmission loss at a wavelength of

at a diameter of 20 mm at a wavelength of 1.55 µm. In [0039] Preferably, the optical fiber according to the this case, the increase in loss of the optical fiber is small length processing by winding like a coll at a terminal of optical cable and the like. The optical fiber 10, 20 preferably has a bending loss of 0.1 dB/m or less at a present invention has a bending loss of 0.1 dB/m or less even when bent into a small diameter upon excessdiameter of 15 mm at a wavelength of 1.55 µm, and more preferably has a bending loss of 0.1 dB/m or less (0040) Fig. 6 is a graph showing an example of preat a diameter of 10 mm at a wavelength of 1.55 μm.

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G610 Indicates a relationship yielding a Petermann-I mode field diameter of 8.0 μm at a wavelength of 1.55 ferred range of the relative refractive index difference Δ, and outer diameter 2a of the core region in the optical liber having the stepped refractive indexprofile 200 (first whereas the ordinate indicates the outer diameter. 2a of termann-I mode flekt diameter of 6 μm at a wavelength of 1.3 µm, curve 630 Indicates a relationship yielding a length of 1.3 µm. The area surrounded by these four embodiment) . In Fig. 6, the abscissa indicates the relative refractive index difference Δ_1 of the core region 11, the core region 11 of the optical fiber 10. In Fig. 6, curve μm, curve G620 indicates a relationship yielding a Pechromatic dispersion of +12 ps/nm/km at a wavelength of 1.55 µm, and curve 640 indicates a relationship yielding a chromatic dispersion of -12 ps/nm/km at a wavecurves G610 to G640 is a preferable range.

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optical fiber 10 according to the first embodiment shown Applied examples of the optical fiber according to the present invention will now be explained. Each of samples prepared has the same structure as that of the in Figs. 1A and 1B except that no carbon coat 60 is provided. Fig. 7 is a table listing various items in each of he optical fibers according to Samples 1 to 5. [0041]

is constituted by silica glass doped with GeO2, whereas the cladding region is constituted by pure silica glass. The relative refractive index difference A; of the core the outer diameter 2a of the core region is 5.5 µm, the outer diameter 2b of the cladding region is 125 µm, and the outer diameter 2c of the coating layer is 250 μm . In the optical fiber of Sample 1, the Petermann-I mode field termann-I mode field diameter at a wavelength of 1.55 μπ is 7.9 μm, the chromatic dispersion at a wavelength length is 1.1 µm, the cable cutoff wavelength is 1.0 µm, the bending loss at a bending diameter of 20 mm at a wavelength of 1.55 µm is 0.04 dB/m, the bending loss In the optical fiber of Sample 1, the core region region with reference to the cladding region is 0.85%, of 1.3 µm is -6.8 ps/nm/km, and the chromatic disperdiameter at a wavelength of 1.3 µm is 6.5 µm, the Pesion at a wavelength of 1.55 µm is +8.6 ps/nm/km. Also, in the optical fiber of Sample 1, the 2-m cutoff waveat a bending diameter of 15 mm at a wavelength of 1.55 km or less. The value of microbend loss is measured with a wire mesh bobbin, and is smaller by about one μπ is 0.3 dB/m, the bending loss at a bending diameter of 10 mm at a wavelength of 1.55 µm is 2 dB/m, and the microbend loss at a wavelength of 1.55 µm is 0.01 dB/ digit than that of a typical single-mode optical fiber havloss at a wavetength of 1.3 µm is 0.37 dB/km, whereas the transmission loss at a wavetength of 1.55 µm is 0.21 ing a zero-dispersion wavelength in the 1.3-µm band. Further, in the optical fiber of Sample 1, the transmission

[0043] Measurement of microbend loss using a wire mesh bobbin is specifically described in J.F. Libert, et al., The New 160 Gigabit WDM Challenge for Submarine Cable Systems", International Wire & Cable System Proceedings 1998, p. 377 (1-Long length lest on wire (0044) In the optical fiber of Sample 2, the core region is constituted by silica glass doped with GeO2, whereas is 6.4 µm, the Petermann-I mode field diameter at a slon at a wavelength of 1.3 µm is -4.6 ps/nm/km, and the chromatic dispersion at a wavelength of 1.55 µm is the cladding region is constituted by silica glass doped with F element. The relative refractive index difference gion is 0.70%, the outer diameter 2s of the core region is 5.8 µm, the outer diameter 2b of the cladding region is 125 µm, and the outer diameter 2c of the coating layer mann-I mode field diameter at a wavelength of 1.3 µm Δ_1 of the core region with reference to the cladding reis 250 µm. In the optical liber of Sample 2, the Peterwavelength of 1.55 µm is 7.4 µm, the chromatic disper-+11.0 ps/nm/km. Also, in the optical fiber of Sample 2, the 2-m cutoff wavelength is 1.2 µm, the cable cutoff m or less, the bending loss at a bending diameter of 15 wavelength is 1.1 µm, the bending toss at a bending diameter of 20 mm at a wavelength of 1.55 μm is 0.01 dB/ of 1.55 µm is 0.1 dB/m, and the microbend loss at a mm at a wavelength of 1.55 µm is 0.02 dB/m, the bending loss at a bending diameter of 10 mm at a wavelength mesh), Fig. 5.

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wavelength of 1.55 µm is 0.01 dB/km or less. Further, in the optical fiber of Sample 2, the transmission loss at a wavelength of 1.3 µm is 0.35 dB/km, whereas the transmission loss at a wavelength of 1.55 µm is 0.20 dB/

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In the optical fiber of Sample 3, the core region is constituted by silica glass doped with ${\rm GeO}_2$, whereas the cladding region is constituted by silica glass doped is 4.9 µm, the outer diameter 2b of the cladding region mann-I mode field diameter at a wavetength of 1.3 µm sion at a wavelength of 1.3 µm is -10.7 ps/nm/km, and the chromatic dispersion at a wavelength of 1.55 µm is m, the bending lose at a bending diameter of 15 mm at a wavelength of 1.55 µm is 1.5 dB/m, the bending loss of 1.3 µm is 0.36 dB/km, whereas the transmission lose with Felement. The relative refractive index difference Δ₁ of the core region with reference to the cladding region is 0.70%, the outer diameter 2s of the core region is 125 µm, and the outer diameter 2c of the coating layer is 6.3 µm, the Petermann-I mode field dlamater at a wavelength of 1.55 µm is 7.7 µm, the chromatic disper-+7.7 ps/nm/km. Also, in the optical fiber of Sample 3, the 2-m cutoff wavelength is 1.0 µm, the cable cutoff wavelength is 0.9 µm, the bending loss at a bending diameter of 20 mm at a wavelength of 1.55 µm is 0.18 dB/ at a banding diameter of 10 mm at a wavelength of 1.55 µm is 13 dB/m, and the microbend loss at a wavelength of 1.55 µm is 0.01 dB/km or less. Further, in the optical liber of Sample 3, the transmission loss at a wavelength is 250 µm. In the optical fiber of Sample 3, the Peter at a wavelength of 1.55 µm is 0.21 dB/km. [0045]

[0046] In the optical fiber of Sample 4, the core region is constituted by silica glass doped with GaO₂, whereas the cladding region is constituted by pure silica glass. the optical fiber of Sample 4, the Petermann-I mode field diameter at a wavelength of 1.3 µm is 6.1 µm, the Pe-The relative refractive index difference A₁ of the core the outer diameter 2s of the core region is 5.3 µm, the outer diameter 2b of the cladding region is 80 µm, and the outer diameter 2c of the coating tayer is 170 µm. In termann-I mode field diameter at a wavelength of 1.55 μm is 7.2 μm, the chromatic dispersion at a wavelength of 1.3 μm is -7.0 ps/nπ/km, and the chromatic disperregion with reference to the cladding region is 0.75%, sion at a wavelength of 1.55 µm is +7.2 ps/nm/km. Also, in the optical fiber of Sample 4, the 2-m cutoff waveloss at a bending diameter of 15 mm at a wavelength of 1.55 µm is 0.05 dB/m, the bending loss at a bending the transmission loss at a wavelongth of 1.3 µm is length is 1.0 μm, the cable cutoff wavelength is 1.0 μm, the bending loss at a bending diameter of 20 mm at a wavelength of 1.55 µm is 0.01 dB/m or less, the bending diameter of 10 mm at a wavelength of 1.55 µm is 0.3 JB/m, and the microbend lose at a wavelength of 1.55 um is 0.1 dB/km. Further, in the optical liber of Sample 0.42 dB/km, whereas the transmission loss at a waveength of 1.55 µm is 0.23 dB/km.

1.1%, the outer diameter 2a of the core region is 6.5 µm, the bending toss at a bending diameter of 15 mm at a is constituted by silica glass doped with ${\sf GeO}_2$, whereas Also, the refrective index profile of the core region has a form approximating an lpha-power distribution where lpha= 2.5. The relative refractive index difference Δ_1 of the core region with reference to the cladding region is the outer diameter 2b of the ctadding region is 125 μm, and the outer diameter 2c of the coating layor is 250 µm. in the optical liber of Sample 5, the Petermann-I mode field diameter at a wavelength of 1.3 µm is 5.3 µm, the Petermann-i mode field diamater at a wavalength of length of 1.3 µm is -8.0 ps/nm/km, and the chromatic dispersion at a wavelength of 1.55 µm is +6.2 ps/nm/ km. Also, in the optical fiber of Sample 5, the 2-m cutoff the cladding region is constituted by pure silica glass 1.55 µm is 6.2 µm, the chromatic dispersion at a wavewavelength is 1.25 µm, the cable cutoff wavelength is 1.16 µm, the bending loss at a bending diameter of 20 wavelength of 1.55 µm is 0.01 dB/m or less, the bending loss at a bending diameter of 10 mm at a wavelength of 1.55 µm is 0.01 dB/m or less, and the microbend loss mm at a wavelength of 1.55 µm is 0.01 dB/m or loss, at a wavelength of 1.55 µm is 0.01 dB/km or less. Further, in the optical fiber of Semple 5, the transmission loss at a wavelength of 1.3 µm is 0.47 dB/km, whereas the transmission loss at a wavelength of 1.55 µm is 0.24 dB/km. Though each of the optical fibers of Samples 1 to 5 has a cladding region with a small outer dlameter 2b and thus exhibits a low rigidity, he value of microband loss is amailer than that of a typical single-mode' optical a 8

vention comprtsing the above-mentioned structure can be employed in various optical components such as an optical liber tape, an optical cable, and an optical con-The optical liber according to the present innector equipped with an optical fiber. [0048] 2

(0049) Fig. 8 is a view showing a schematic structure has the same structure as that of the optical fiber 10 (20) of an optical fiber tape employing the optical fiber according to the present invention (an optical fiber tape according to the present invention). This optical fiber tape 150 comprises a plurality of optical fibors integrally coated with a resin, whereas each of the optical fibers having the above-mentioned structure. ş

[0050] Fig. 9 is a view showing a schematic structure fiber according to the present invention). This aptical of an optical connector equipped with an optical fiber employing the optical fiber according to the present inconnector equipped with an optical fiber comprises the vention (an optical connector equipped with an optical oplical fiber 10 (20) having the structure mentioned above, and a connector 500 attached to a leading end part of the optical fiber 10 (20). When this optical connector equipped with an optical fiber is used, a system employing the optical fiber 10 (20) can be operated more

Fig. 10A is a view showing a schematic struc-[0051]

0047] In the optical fiber of Sample 5, the core region

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R 8 ä a chromatic dispersion with an absolute value of 12 ps/ mode field diameter of 8.0 µm or less at a wavelength of 1.55 μm , a cutoff wavelength of 1.26 μm or less, and a configuration having a mode field diameter of 8.0 µm or less at a wavelength of 1.55 µm; a configuration hav-[0052] As explained in the foregoing, the present invention is typically realized by a configuration having a пт/кт от less at wavelengths of 1.3 µm and 1.55 µm; or less at a wavelength of 1.55 µm, a cut off wavelength of 1.26 µm or less, and a microb end loss of 0.1 dB/km ing a mode field diameter of 8.0 µm or less at a wavelength of 1.55 µm, a cutoff wavelength of 1.28 µm or or a configuration having a mode field diamater of 6.5 μm or less at a wavelength of 1.55 μm, a cutoff wavelength of 1.26 µm or less, and a transmission loss of 0.5 dB/km or less at a wavelength of 1.3 µm. Various typical configurations such as those mentioned above make it of wavelength bands of 1.3 µm and 1.55 µm, while anless, and a proof level of 1.2% or more in a proof test; possible to trensmit signals with a high bit rate in both abling high-density packaging into an optical cable.

Claims

1. An optical fiber having:

- a mode field diameter of 8.0 µm or less at a a cutoff wavelength of 1.26 µm or tess; wavelength of 1.55 µm;
 - of 12 ps/nm/km or less at wavelengths of 1.3 a chromatic dispersion with an absolute value μm and 1.55 μm and/or
 - a microbend loss of 0.1 dB/km at the wavelength of 1.55 µm.

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An optical fiber according to claim 1, having a proof level of 1.2% or more in a proof test. તં

- An optical fiber according to claim 2, wherein the proof level in the proof test is 2% or more. mi
- An optical liber according to claim 2, wherein the proof level in the proof test is 3% or more.
- An optical fiber according to claim 2, wherein the proof level in the proof test is 4% or more.
- An optical fiber according to claim 1, wherein the mode field diameter at the wavelength of 1.55 μm is 6.5 µm or less.
- An optical fiber according to claim 6, having a trans mission loss of 0.5 dB/km or less at the wavelength

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mission loss of 0.3 dB/km or less at the wavelength An optical fiber according to claim 7, having a trans of 1.3 µm.

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- An optical fiber according to claim 1, wherein the mode fleld diameter at the wavelength of 1.3 µm is 5.0 µm or more.
- An optical fiber according to claim 9, wherein the mode field diameter at the wavelength of 1.3 µm is
 - 6.0 µm or more.
- . An optical liber according to claim 1, wherein the mode field diameter at the wavelength of 1.55 μm ls 7.0 µm or more.
- An optical fiber according to claim 1, wherein the cutoff wavelength is 1.0 µm or more. 2
- ing loss of 0.1 dB/m or less at a diameter of 20 mm An optical fiber according to claim 1, having a bandat the wavelength of 1.55 µm.
- ing loss of 0.1 dB/m or less at a diameter of 15 mm An optical fiber according to claim 1, having a bendat the wavelength of 1.55 µm.
- An optical fiber according to claim 1, having a bending loss of 0.1 dB/m or less at a diameter of 10 mm at the wavelength of 1.55 µm. 5.

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- ery of said core region, having maximum and min-imum outer diameters yielding a difference of 1.0 An optical fiber according to claim 1, comprising a core region extending along a predetermined axis; and a cladding region, provided on an outer periph µm or less therebetween. ĕ
- An optical fiber according to claim 1, comprising a core region extending along a predetermined axis; and a cladding region, provided on an outer periph-

ery of seld core region, having maximum and minmum outer diameters yielding a difference of 0.5

An optical fiber according to claim 1, comprtsing a core region extending atong a predetermined axis, and a cladding region provided on an outer pertphµm or less therebetween.

wherein a core eccentricity amount defined by the amount of deviation of a center of said core region with respect to a center of said cladding region ery of said core region; is 0.5 µm or less.

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An optical fiber according to claim 1, comprising a core region extending along a pradetermined axis, and a cladding region provided on an outer periph <u>6</u>

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8 gion with respect to a center of said cladding region wherein a core accentricity amount defined by the amount of deviation of a center of said core reery of sald core region; is 0.2 µm or less.

- An optical fiber according to claim 19, wherein the mode field diameter at a wavelength of 1.55 µm is 6.5 µm or less. 8
- 8 core region extending along a pradetermined axts; and a cladding region, provided on an outer pertphery of said core region, having an outer dlameter of An optical fiber according to claim 1, comprising a
- 2 ery of said cladding region, having an outer diameprising a coating layer, provided on an outer periph-An optical fiber according to claim 21, further comter of 250±30 µm. য়
- mode field diameter at the wavelength of 1.55 µm An optical liber according to claim 22, wherein the Is 6.5 µm or less. ន
- said core region; and a coating layer, provided on an outer perphery of said cladding region, having 24. An optical fiber according to claim 1, comprising a core region extending along a predetermined axis; a cladding region provided on an outer periphery of an outer diameter of 250±30 μm.

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mode field diameter at the wavelength of 1.55 µm An optical fiber according to claim 24, wherein the is 6.5 µm or tess.

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- mined axis, and a cladding region provided on an An optical fiber according to claim 1, comprising, at least, a core region extending along a predeterouter periphery of said core region; and **5**8
 - having such a refractive index profile that a part corresponding to said core region has a sub-

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stantlatly single-peak form whereas a part corresponding to said cladding region has a substantially

- 27. An optical fiber according to claim 1, comprising, at GeO_2 , extending along a predatermined axis; and least, a core region, made of ellica glass doped with a cladding region made of substantially pure silica glass and provided on an outer periphery of said core region.
- An optical fiber according to claim 1, comprising, at a cladding region made of silica glass doped with least, a core region, made of silica glass dopod with GeO₂, extending along a predetermined exis; and fluorine and provided on an outer periphery of said
- An optical liber according to claim 1, comprising, at mined axis, and a cladding region provided on an least, a core region extending along a predaterouter periphery of said core region; and Ŕ
 - having a refractive index profile with a form to 5 within the range from a part ylolding the maxi-Imum refractive index in a portion corresponding to mum refractive index to a part yielding half the maxapproximating an lpha-power distribution where lpha = 1 said core region.

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- 30. An optical fiber according to claim 1, comprising, at mined axis, and a cladding region provided on an least, a core region extending along a predetor outer periphery of said core region;
 - eaid cladding region having an inner cladding provided on the outer periphery of said core region; and an outer cladding, provided on an outer pertphery of sald inner cladding, having a refractive index higher than that of said inner cladding.
- 31. An optical fiber according to claim 1, having a fatigue coefficient n of 50 or more.

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- An optical liber according to claim 31, comprising a a cladding region provided on an outer pertphery of said core region, and a carbon coat provided on an core region extending along a predetermined exis outer periphery of said cladding region. 덣
- 33. An optical liber according to claim 1, comprising a core region extending along a predetermined axis; a cladding region provided on an outer periphery of said core region; and a coating layer, provided on an outer perlphery of sald cladding region, having
- An optical fiber according to claim 33, wherein said coating layer comprises an inner coating, provided on the outer periphery of said cladding region, hav ğ

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- An optical fiber according to claim 34, wherein said outer coating has a thickness of 15 µm or more. 35.
- An optical fiber according to claim 33, wherein said coating layer is constituted by a single layer. 8
- An optical fiber according to claim 36, wherein said coating layer has a thickness of 15 µm or more. 37.
- An optical fiber according to claim 37, wherein said coating layer has a Young's modulus of 10 kg/mm² 38

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An optical fiber according to ctaim 1, comprising, at least, a core region extending along a predetermined axis; a cladding region provided on an outer periphery of sald core region; and a coating layer, provided on an outer periphery of said cladding region, having an outer diameter of 200 μm or less. 39

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- An optical fiber according to claim 1, comprising, at mined axis; and a cladding region, provided on an least, a core region extending along a predeterouter periphery of said core region, having an outer diameter of 60 to 100 µm. å
- An optical fiber according to claim 33, wherein the mode field diameter at the wavelength of 1.55 µm is 6.5 µm or less ₽.
- An optical fiber according to claim 40, having a bending loss of 0.1 dB/m or less at a diameter of 20 mm at the wavelength of 1.55 µm. Ğ
- An optical fiber according to claim 40, having a bending loss of 0.1 dB/m or less at a diameter of 15 mm at the wavelength of 1.55 µm. g
- An optical fiber according to claim 40, having a bending loss of 0.1 dB/m or less at a diameter of 10 mm at the wavelength of 1.55 µm. 4.

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- An optical fiber tape including the optical fiber according to one of claims 1-44. ą.
- An optical cable including the optical liber according to one of claims 1-44. ê,
- comprising the optical fiber according to one of claims 1-44 and a connector attached to a leading 47. An optical connector equipped with an optical fiber end part of said optical fiber

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- 48. An optical fiber having:
- a mode fleid diameter of 8.0 µm or less at a a cutoff wavelength of 1.26 µm or less: wavelength of 1.55 µm; and
- a proof level of 1.2% or more in a proof test.
- matic dispersion with an absolute value of 12 ps/ nm/km or less at wavelengths of 1.3 µm and 1.55 An optical fiber according to claim 48, having a chro-**€**

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- An optical fiber according to claim 48, having a microbend loss of 0.1 dB/km or less at the wavelength of 1.55 µm. S,
- An optical fiber according to claim 48, wherein the proof level in the proof test is 2% or more.
- An optical fiber according to claim 48, wherein the proof level in the proof test is 3% or more. 25
- 53. An optical fiber according to claim 48, wherein the
- An optical fiber according to claim 48, wherein the proof level in the proof test is 4% or more.
 - mode field diameter at the wavelength of 1.55 µm is 6.5 µm or less.
- 55. An optical fiber according to claim 54, having a transmission loss of 0.5 dB/km or less at a wavelength of 1.3 µm.

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- 56. An optical fiber according to claim 55, having a transmission loss of 0.3 dB/km or less at the wavelength of 1.55 µm.
- mode field diameter at a wavelength of 1.3 µm is An optical fiber according to claim 48, wherein the 5.0 µm or more. 57

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- An optical fiber according to claim 57, wherein the mode field diameter at the wavelength of 1.3 µm is 6.0 µm or more. ģ
- An optical fiber according to claim 48, wherein the mode field dlameter at the wavelength of 1.55 µm 29
- 60. An optical fiber according to claim 48, wherein the cutoff wavelength is 1.0 µm or more.

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- bending loss of 0.1 dB/m or less at a diameter of 20 An optical fiber according to claim 48, mm at the wavelength of 1.55 µm.
- bending loss of 0.1 dB/m or less at a diameter of 15 An optical fiber according to claim 48, having a ğ

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mm at the wavelength of 1.55 µm.

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- bending loss of 0.1 dB/m or less at a dlameter of 10 An optical fiber according to claim 48, having a mm at the wavelength of 1.55 µm.
- ery of said core region, having maximum and min-imum outer diameters yielding a difference of 1.0 An optical fiber according to claim 48, comprising a core region extending along a predatermined axis; and a cladding region, provided on an outer periphµm or less therebetween
- An optical fiber according to claim 48, comprising a core region extending along a pradetermined axis; and a cladding region, provided on an outer periph-Imum outer dlameters yielding a difference of 0.5 ery of said core region, having maximum and min um or less therebetween. 65

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An optical fiber according to claim 48, comprising a core region extending along a predetermined axis, and a cladding region provided on an outer peripheny of said core region; 99

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- wherein a core accentricity amount defined by gion with respect to a center of said cladding region the amount of deviation of a center of sald core rels 0.5 µm or less.
- An optical fiber according to claim 48, comprising a and a cladding region provided on an outer periphcore region extending atong a predetermined axis, ery of said core region;
- 2 the amount of deviation of a center of said core rewherein a core eccentricity emount defined by gion with respect to a center of said cladding region ls 0.2 µm or less.
- mode field dlameter at the wavelength of 1.55 µm An optical fiber according to claim 67, wherein the is 6.5 µm or less. ģ

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â An optical fiber according to claim 48, comprising a core region extending along a predetermined axis; and a cladding region, provided on an outer periphery of said core region, having an outer diameter of ĝ

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An optical fiber according to claim 69, further com-prising a coating layer, provided on an outer periphery of said cladding region, having an outer diameler of 250±30 µm.

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mode field diameter at the wavelength of 1.55 µm 71. An optical fiber according to claim 70, wherein the is 6.5 µm or less,

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An optical fiber according to claim 48, comprising a

- said core region; and a coating tayer, provided on an outer periphery of said cladding region, having a cladding region provided on an outer pariphery of core region extending along a predetermin'ed axis. an outer diameter of 250±30 μm.
- 73. An optical liber according to claim 72, wherein the mode field diameter at the wavelength of 1,55 µm is 6.5 µm or less.
- mined axis, and a cladding region provided on an 74. An optical fiber according to claim 48, comprising, et least, a core region extending along a prodeter outer periphery of said core region; and
 - having such a refractive index profile that a part corresponding to said core region has a subsponding to said cladding region has a substantially stantially single-peak form whereas a part correflat form,
- silica glass and provided on an outer periphery of An optical fiber according to claim 48, comprising, and a cladding region made of substantially pure at least, a core region, made of silica glass doped with GeO₂, extending along a predetermined axis; said core region. 35

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with GeO₂, extending atong a prodetermined exis; and a cladding region made of silica glass doped at loast, a coro region, made of silica glass deped with fluorine and provided on an outer periphery of 76. An optical fiber according to claim 48, comprising said core region.

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- mined axis, and a cladding region provided on an An optical fiber according to claim 48, comprising, at least, a core region extending along a predeter outer periphery of said core region; and Ľ
 - having a refractive index profile with a form to 5 within the range from a part yielding the maximum refractive index to a part yielding half the maxmum refrective index in a portion corresponding to approximating an α -powor distribution where α = 1 said core region.
- An optical liber according to claim 48, comprising. mined axis, and a cladding region provided on an at least, a core region extending along a predater outer periphery of said core region; 8,
- provided on the outer pertphery of said core region; said cladding region having an Inner cladding ery of said Inner cladding, having a refractive Index and an outer cladding, provided on an outer portphhigher than that of said inner cladding
- An optical liber according to claim 48, having a faligue coefficient n of 50 or more. ĕ

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- 81. An optical fiber according to claim 48, comprising a core region extending along a predetermined axis; a cladding region provided on an outer periphery of said core region; and a coating layer, provided on an outer periphery of said cladding region, having a thickness of 37.5 µm or less.
- coating layer comprises an inner coating, provided said inner coating, having a Young's modulus of 10 ing a Young's modulus of 0.2 kg/mm² or less; and An optical fiber according to claim 81, wherein sald on the outer periphery of said cladding region, havan outer coating, provided on an outer periphery of kg/mm² or more 얺
- An optical fiber according to claim 82, wherein sald outer coating has a thickness of 15 µm or more. ខ្ល
- An optical fiber according to claim 81, wherein said coating layer is constituted by a single layer. Z,

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- An optical fiber according to claim 84, wherein said coaling layer has a thickness of 15 µm or more. ä
- An optical fiber according to claim 84, wherein said coating layer has a Young's modulus of 10 kg/mm² ģ
- 23 An optical fiber according to claim 48, comprising, mined axis; a cladding region provided on an outer at least, a core region extending along a predeterperiphery of sald core region; and a coating layer, provided on an outer pariphery of said cladding reglon, having an outer diameter of 200 µm or less. 87.
- 88. An optical fiber according to claim 48, comprising, outer periphery of said core region, having an outer at least, a core region extending along a predetermined axis; and a cladding region, provided on an diameter of 60 to 100 µm.
- mode field diameter at the wavelength of 1.55 µm An optical liber according to claim 81, wherein the is 6.5 µm or less. ĕ
- An optical liber according to claim 88, having a bending loss of 0.1 dB/m or less at a diameter of 20 mm at the wavelength of 1.55 µm. 8
- bending loss of 0.1 dB/m or less at a dlameter of 15 91. An optical fiber according to claim 88, mm at the wavelength of 1.55 µm.

92. An optical fiber according to claim 88, having a bending loss of 0.1 dB/m or less at a diameter of 10 mm at the wavelength of 1.55 µm.

- 93. An optical fiber tape including the optical fiber according to one of claims 48-92.
- 94. An optical cable including the optical liber according to one of claims 48-92.
- comprising the optical liber according to one of An optical connector equipped with an optical fiber claims 48-92 and a connector attached to a leading end part of said optical fiber.
- An optical fiber having:

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- a mode field diameter of 6.5 µm or less at a a transmission loss of 0.5 dB/km or less at a a cutoff wavelength of 1.28 µm or less; wavelength of 1.55 µm; wavelength of 1.3 µm.
- matic dispersion with an absolute value of 12 ps/ An optical fiber according to claim 96, having a chronm/km or less at the wavelengths of 1.3 µm and 97.
 - - 98. An optical fiber according to claim 96, having a microbend loss of 0.1 dB/km or less at the wavelength
- An optical liber according to claim 96, having a proof level of 1.2% or more in a proof test.
- 100.An optical fiber according to claim 99, wherein the proof level in the proof test is 2% or more.
- 101.An optical fiber according to claim 99, wherein the proof level in the proof test is 3% or more.
- 102.An optical fiber according to claim 99, wherein the proof level in the proof test is 4% or more.
- 103.An optical fiber according to claim 96, having a transmission loss of 0.3 dB/km or less at the wave

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- length of 1.55 µm.
- 104.An optical fiber according to claim 96, wherein the mode field diameter at the wavelength of 1.3 µm is 5.0 µm or more.
- 105.An optical fiber according to claim 96, cutoff wavelength is 1.0 µm or more
- 106.An optical fiber according to claim 96, having a bending loss of 0.1 dB/m or less at a dlameter of 20 mm at the wavelength of 1.55 µm.

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107.An optical liber according to claim 96, having a bending loss of 0.1 dB/m or less at a diameter of 15 mm at the wavelength of 1.55 µm.

having a bending toss of 0.1 dB/m or less at a diameter of 10 108.An optical liber according to claim 98, mm at the wavelength of 1.55 µm.

109.An optical fiber according to claim 98, comprising a core region extending along a predetermined exis; and a cladding region, provided on an outer periphimum outer diameters yielding a difference of 1.0 ery of seld core region, having maximum and minµm or less therebetween. 110.An optical fiber according to claim 88, comprising a core region extending along a predetermined axis; and a cladding region, provided on an outer periphery of sald core region, having maximum and minimum outer dlameters yleiding a difference of 0,5 µm or less therebetween.

111.An optical fiber according to claim 96, comprising a and a cladding region provided on an outer periphcore region extending along a predetermined axis ery of said core region;

wherein a core eccentricity amount defined by the amount of deviation of a center of said core reglon with respect to a center of said cladding region is 0.5 µm or less. 112.An optical fiber according to claim 96, comprising a and a cladding region provided on an outer periphcore region extending along a predetermined axis, ery of said core region;

wherein a core eccentricity amount defined by the amount of deviation of a center of said core region with respect to a center of said cladding region ls 0.2 µm or less. 113.An optical fiber according to claim 112, wherein the mode field diameter at the wavelength of 1.55 µm ls 6.5 µm or less.

\$ 114.An optical fiber according to claim 96, comprising a and a cladding region, provided on an outer periphery of said core region, having an outer diameter of core region extending along a predetermined axls;

prising a coating layer, provided on an outer periph-15.An optical fiber according to claim 114, further comery of sald cladding region, having an outer diame ter of 250±30 µm.

118.An optical fiber according to claim 115, wherein the mode fleid diameter at the wavelength of 1.55 µm is 6.5 µm or less.

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seld core region; and a coating layer, provided on an outer periphery of sald cladding region, having 117.An optical fiber according to claim 98, comprising a a cladding region provided on an outer pertphery of core region extending along a predetermined axis; an outer diameter of 250±30 µm.

118.An optical fiber according to claim 117, wherein the mode field dlameter at the wavelength of 1.55 µm Is 6.5 µm or less. 119.An optical fiber according to claim 98, comprising. at least, a core region extending along a prodotermined exis, and a cladding region provided on an outer periphery of said core region; and

having such a refractive index profile that a part corresponding to said core region has a substantially single-peak form whereas a part corresponding to said cladding region has a substantially

120.An optical fiber according to claim 98, comprising, at least, a core region, made of silica glass doped with ${\sf GeO}_2$, extending along a predetermined axis; and a cladding region made of substantially pure stilica glass and provided on an outer periphery of said core region.

121.An optical fiber according to claim 96, comprising with GeO₂, extending along a predetermined axis, and a cladding region made of silice glass doped with fluorine and provided on an outer periphery of al least, a core region, made of silica glass depac said core region. 122.An optical fiber according to claim 96, comprising, mined axis, and a cladding region provided on an at least, a core region extending along a prodeter outer periphery of said core region; and

to 5 within the range from a part yielding the maximum refractive index in a portion corresponding to having a refractive index profile with a form approximating an α -power distribution where α = 1 mum refractive index to a part yielding half the maxsaid core region. 123.An optical fiber according to claim 98, comprising. mined axis, and a cladding region provided on an at least, a core region extending along a predaterouter periphery of said core region;

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sald cladding region having an innor cladding provided on the outer periphery of said core region; and an outer cladding, provided on an outer pertphery of said inner cladding, having a refractive index higher than that of said inner cladding 124.An optical fiber according to claim 96, having a tatigue coefficient n of 50 or more.

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a cladding region provided on an outer periphery of said core region; and a coating layer, provided on an outer periphery of said cladding region, having 126.An optical fiber according to claim 96, comprising a core region extending along a predetermined axis; a thickness of 37.5 µm or less.

coating layer comprises an inner coating, provided an outer coaling, provided on an outer periphery of said inner coaling, having a Young's modulus of 10 127.An optical fiber according to claim 128, wherein said Ing a Young's modulus of 0.2 kg/mm² or less; and on the outer periphery of said cladding region, havkg/mm² or more.

128.An optical fiber according to claim 127, wherein said outer coaling has a thickness of 15 µm or more.

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129.An optical fiber according to claim 126, wherein said coating layer is constituted by a single layer.

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130.An optical fiber according to claim 129, wherein said coating layer has a thickness of 15 µm or more. 131.An optical fiber according to claim 130, wherein said 132.An optical liber according to claim 96, comprising, mined axis; a cladding region provided on an outer periphery of said core region; and a coating layer, provided on an outer periphery of said cladding reat least, a core region extending along a predetercoating layer has a Young's modulus of 10 kg/mm² or more.

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133.An optical fiber according to claim 98, comprising, mined axis; and a cladding region, provided on an outer periphery of said core region, having an outer at least, a core region extending along a predeterdiameter of 60 to 100 µm.

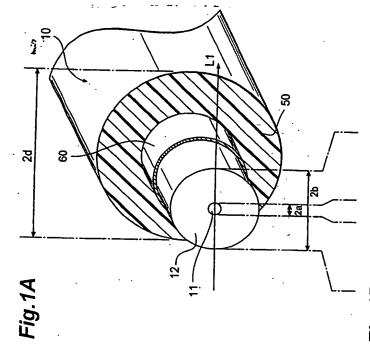
gion, having an outer diameter of 200 µm or less.

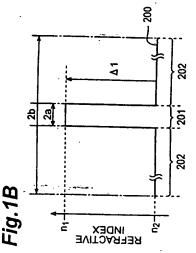
134.An optical fiber according to claim 126, wherein the mode field diameter at the wavelength of 1.55 µm is 6.5 µm or less. 135.An optical fiber according to claim 133, having a bending loss of 0.1 dB/m or less at a diameter of 20 mm at the wavelength of 1.55 $\mu\text{m}.$ 136.An optical fiber according to claim 133, having a bending loss of 0.1 dB/m or less at a diameter of 15 mm at the wavelength of 1.55 µm.

137.An optical fiber according to claim 133, having a bending loss of 0.1 dB/m or less at a diameter of 10 mm at the wavelength of 1.55 µm.

138.An optical fiber tape including the optical fiber according to one of claims 96-137

139.An optical cable including the optical fiber according to one of claims 96-137. 140.An optical connector equipped with an optical fiber comprising the optical fiber according to one of claims 96-137 and a connector attached to a leading end part of said optical fiber.





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REFRACTIVE INDEX

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Fig.2C

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Fig.2A

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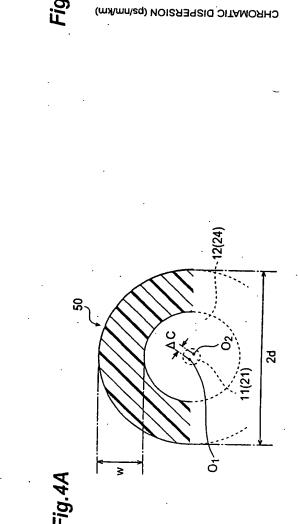
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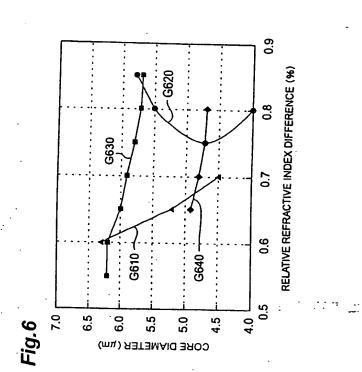
Fig.2B

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1.5 1.55 1.6 WAVELENGTH (µm)

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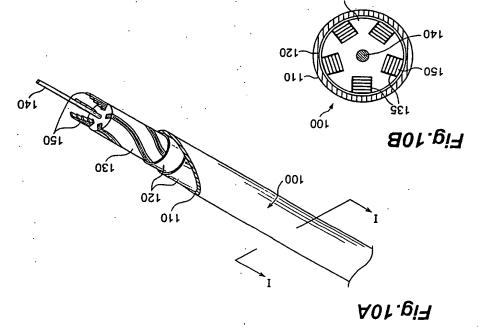
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PZ.O	6Z.0 ·	12.0	0.20	12.0	(dB/km)	hudee: @loos
74.0	24.0	95.0	SE.O	46.0	(dB/km)	(m 4 23.1 (B) 220 J NOISSIMENARI
0.01 or LESS	1.0	0.01 or LESS	0.01 or LESS	201 or LESS		(m 4 £.f.@) SSOJ NOISSIMSMART
0'01 OL FERR	6.0	13	1.0		(dB/km)	NICKOBEND FORS (@1.55 mm)
0'01 OL LESS	80.0	8.1	20.0	5	(m/8b)	BENDING FORS (10mm & 1.55 µm)
0.01 or LESS	0.01 or LESS	91.0		6.0	(m/gp)	BENDING FO2S (12mm ¢ ,@1.55 km)
8r.r	002140700		0.01 or LESS	≱0.0	(m/8b)	BENDING LOSS (20mm & ,@1.55 μ m)
		6.0	1.1	↓	(w n)	CABLE CUTOFF WAVELENGTH
1.25	1.1		5.1	1.1	(w n)	Sm CUTOFF WAVELENGTH
5.9	2.7	LT	11	9.8	(ps/nm/km)	CHROMATIC DISPERSION (@1.55 m)
8-	٤-	T.01-	9·t -	8.8-	(bayuuykw)	CHROMATIC DISPERSION (@1.3 mm)
. 6.2	S.T	T.T	4.7	6.7	(w n)	MFD(@1.55 µ m)
5.3	1.9	6.3	4.8	č. 8	(шп)	MFD(@1.3 µ m)
S20	071	520	520	. 092	(ωπ)	COATING OUTER DIAMETER
125	08	150	125	126	(w n)	CLADDING DIAMETER
8.8	5.3	6.4	8.8	8.8	(w n)	CORE DIAMETER
1.1	27.0	07.0	07.0	59.0		RELATIVE REFRACTIVE INDEX DIFFER
SIO2	SOis	F-SiO2	E-8102	. ZOIS	1707 30113	
GeOz-SIO2	GeO2-SiO2	GeO2-SiO2	GeO2-SIO2	2012-2095		CLADDING COMPOSITION
SAMPLE 5	SAMPLE 4				_ 	CORE COMPOSITION
2210,173	A 3 IGMA2	SAMPLE 3	S 3J9MAR	1 3JAWAS		



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